Building Better Bulletin

CANADA

better building bulletin

Division of Building Research
National Research Council
JUNE 1949 TEN CENTS

1 CONDENSATION IN THE HOME

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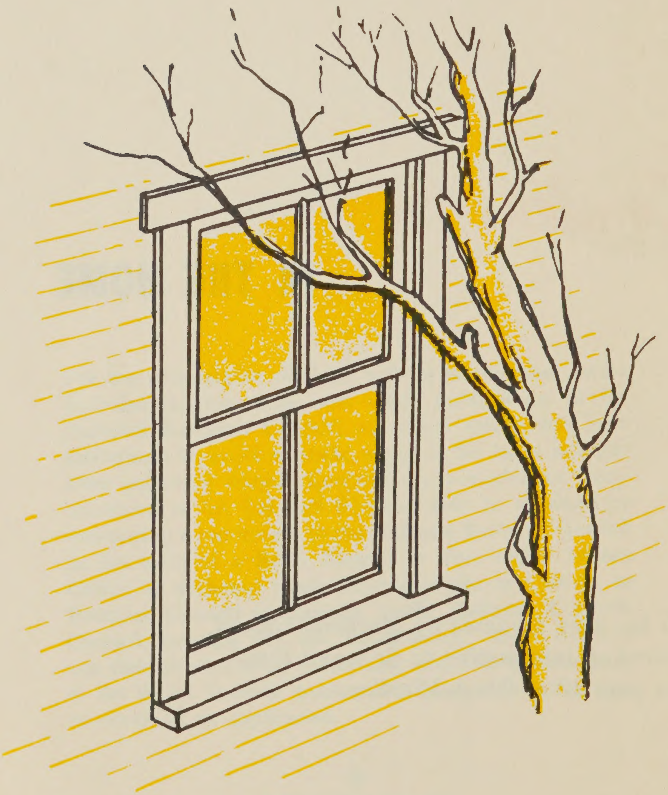
Ottawa, 1971
Cat. No. NR42-1

This is one of a series of bulletins on Better Building Practice; it deals with

Condensation IN THE HOME

It has been prepared by Margaret Gerard, based on information to be found listed on page 19 of this publication.

Condensation on window panes—
a familiar sight in wintertime



Purpose OF BOOKLET

This booklet is written to assist prospective home owners and builders in avoiding the damage that condensation can cause to a home. It must be emphasized that this damage *can* be very great. Consider the following, which is a list of only some of the possible results of condensation and then judge how you can save your house and pocket book by making provision during construction, or afterward, against condensation:

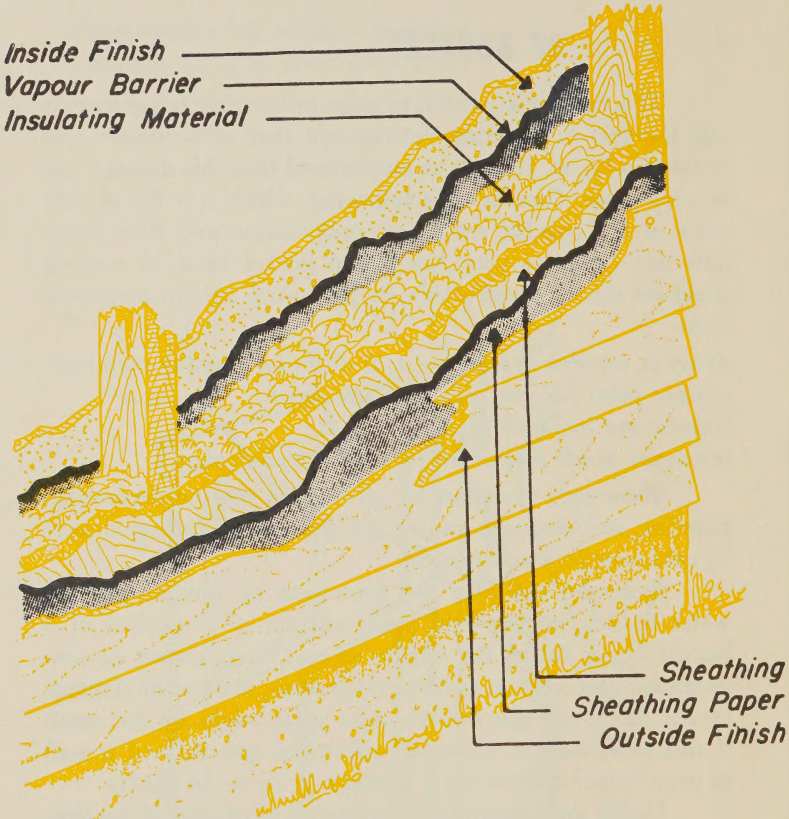
decay in wooden sheathing, studs and roof framing members;
outside paint failures on siding and finish;
stained and loosened plaster;
insulation made ineffective by moisture absorption.

Thousands of dollars are spent each year on decorating, painting, maintenance, and repairs because of damage caused by cold weather condensation.

Everyone has seen the formation of tiny droplets of water or dew on the cold inside surface of a window of a heated home during the winter time. This is known as condensation and when it occurs on windows, little or no damage results. But have you ever thought what might be the result if this condensation occurred within the structure of a wall of your home? This is not a question to be taken lightly.

Unless some means are introduced to prevent it, condensation can and *does* occur in inner wall structures of the insulated houses of to-day, especially in localities with severe winter climates.

Condensation may occur in poorly constructed, uninsulated houses. Unless specific steps are taken to prevent it, the problem becomes acute in good modern construction



where the walls are tightly built, the air spaces filled with insulation, and additional moisture is introduced into the house by artificial humidification.

In order to add to the comfort of the occupants and also to reduce fuel costs, it is now general practice to add

these features during construction—weatherstripping, insulation, caulking, storm windows and doors. In addition to these, automatically controlled heat sources, controlled ventilation and air conditioning have also been introduced. All these make the concentration of water vapour in the house much greater than it would have been with older methods of construction.

This is beneficial from the view-point of health. It brings up new problems relating to the construction of the house, however, as there are now no cracks or joints through which the warm moist air can escape directly to the outside. Insulation in the wall space prevents loss of heat through the walls, but there is often nothing in the wall to prevent the water vapour from flowing through the wall structure. When this warm moist air reaches the cold inner surface of the wall, condensation will occur, bringing with it its damaging results.

Before discussing how best to guard against condensation, let us first consider a few basic facts about water vapour.

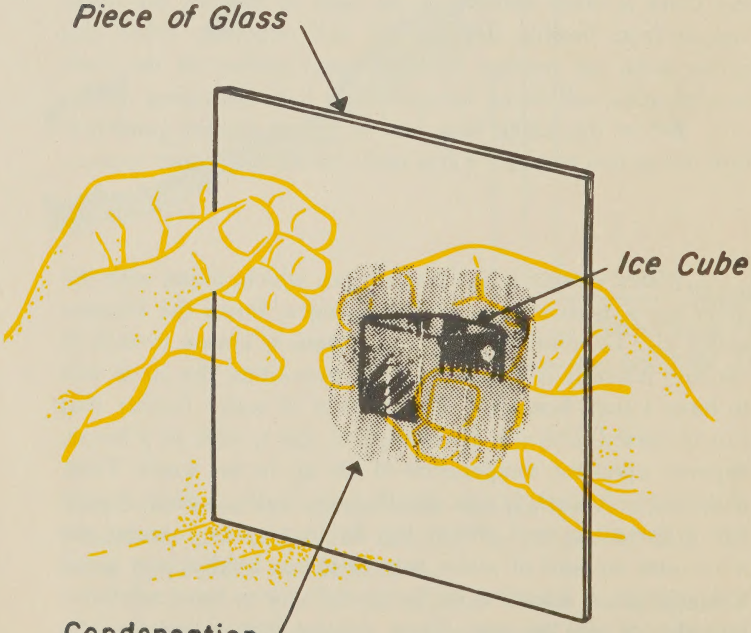
Water Vapour

Water vapour is an invisible gas, which, along with the other gases, such as oxygen and nitrogen, forms the mixture called air. To some extent, water vapour is always present in the air. When it is present in large quantities, the air is said to have a high humidity. The amount of water vapour that can be mixed with the air in a given space, such as a house, depends upon the temperature of the air in the space. Thus, if the air is heated, it can absorb more water vapour than it can if the air is cool. When the air in a space contains the maximum amount of water vapour it can hold at any given temperature, it is said to be "saturated", or to have a relative humidity of 100 per cent. Thus, relative humidity is the per-

centage of water vapour present, at any given temperature, in relation to the maximum amount the space *could* hold at that temperature.

HOW *Condensation* FORMS

To understand the formation of condensation, let us consider a piece of glass held on edge on a table top. The glass and the humid air next to it on both sides are at the same temperature. Now suppose we place an ice cube next to the glass on one side and hold it there.

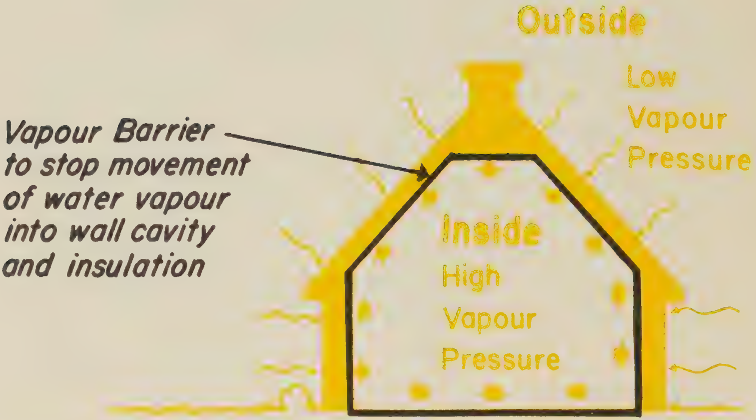


In a few moments beads of moisture will appear on the opposite side of the piece of glass. What has happened? The piece of glass has been cooled by the ice cube, and similarly the vapour-laden air around the glass has been cooled by contact with the cooled glass. This air has been cooled so much that it can no longer hold all the water vapour it contained at the higher temperature. In other words, the temperature of the air has been reduced below its saturation temperature. Thus some of the water vapour, which was formerly an invisible gas mixed with the air, has been "condensed" out of the air in the form of water droplets deposited on the cold surface of the piece of glass.

FLOW OF *Water Vapour*

Water vapour exerts a pressure like all other gases. The greater the amount of water vapour in the air, the greater the pressure. Thus, when water vapour is *added* to the warm air in the house by reason of the normal household activities such as cooking, washing, and bathing, the house becomes an area of high vapour pressure. Outdoors the air is cold and contains little water vapour and therefore the outside may be said to be a low vapour pressure area.

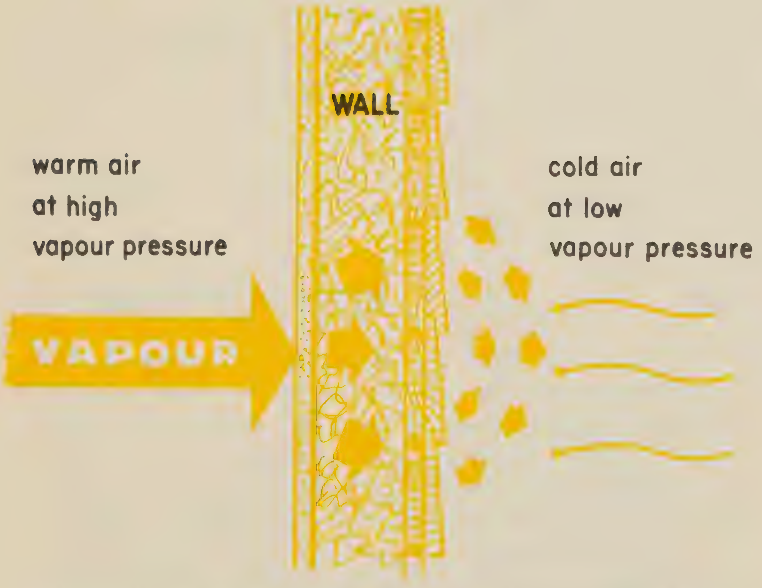
Now water vapour, the same as other gases, tends to flow from a high pressure area to a low pressure area. Consequently the water vapour in the air inside the house is constantly trying to escape from the house to the outdoors. In older houses of relatively loose construction, it could readily escape through cracks around windows and doors, but in houses of tighter construction, the only means of escape is through the material of the walls, ceiling or floor. Most ordinary materials used in building to-day allow water vapour to pass through them quite readily.



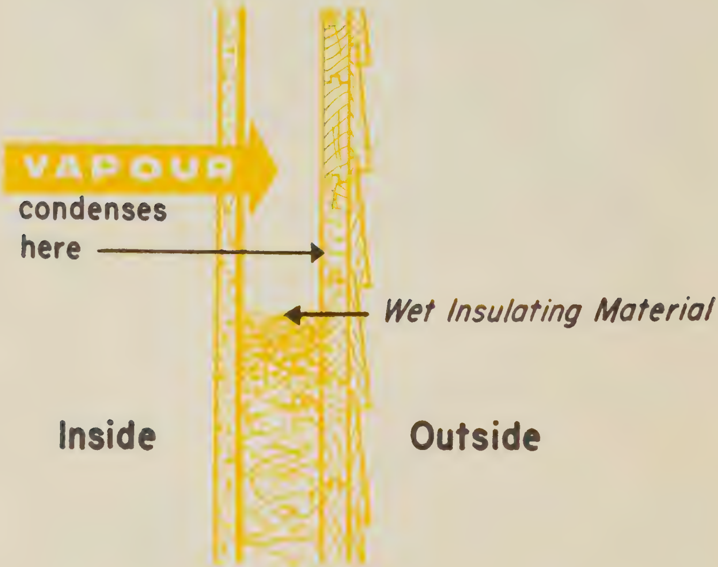
Let us consider a section of an "outside" wall of a house, with warm humid air on the inside and cold air on the outside. If the wall materials offer little resistance to this flow of water vapour, the water vapour will penetrate into the colder inner structure of the wall. As this vapour continues to move toward the cold outside of the wall, it is cooled more and more until it reaches the surface of some cold material which is at a temperature below the saturation temperature of the water vapour.

On the other hand, if the wall space is insulated, the situation may be even more serious as the condensation will probably be absorbed by the insulation. Gradually the insulation will become so water logged that it may be ineffective as an insulating material. On account of its increased weight, it may drop down to the bottom of the stud space.

When wet, some types of insulation tend to hold the moisture for long periods of time; in fact, it may never dry out. Thus, any part of the house that is in contact with wet insulation remains damp for a long time, a condition which will probably lead to rot. Thus we see that the insulation may not only drop down in the stud space, but it may also lose much of its original insulating value. Furthermore, the moisture in the damp insulation will cause deterioration of the sheathing, sills or studding by rot.



SHOWING DIRECTION OF WATER VAPOUR TRAVEL



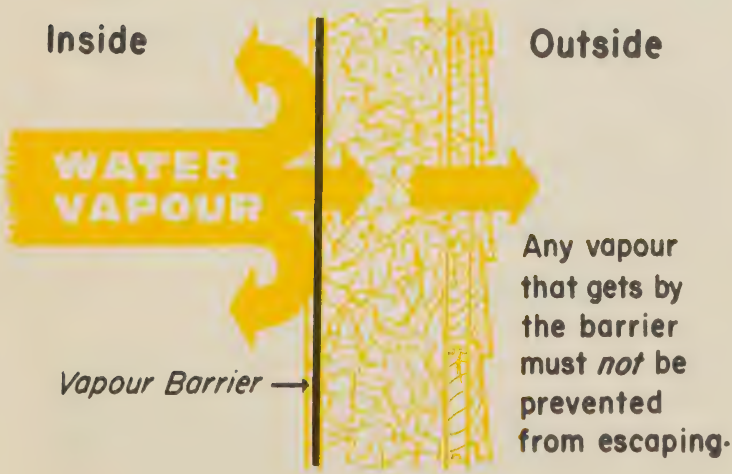
HOW *Condensation* MIGHT BE PREVENTED

One way in which the problem of condensation in the wall structure could be overcome would be to have sufficient ventilation in the house to make the inside and outside vapour pressures nearly equal. This condition would prevent the flow of water vapour from the inside towards the outside but is, of course, ridiculous from the standpoint of comfort.

Another "solution" would be to keep the air in the house as dry as possible. This is impossible because there will always be water vapour added to the air by cooking, washing,

and bathing. It is also not desirable because very dry air irritates the nose and throat and causes dry skin. Nevertheless, the problem of condensation can be minimized by maintaining only enough humidity to relieve the discomfort due to dryness.

In order to prevent condensation in the wall structure, or ceiling, the water vapour must be stopped before it is cooled below the condensation temperature. To accomplish this, the walls and ceiling and sometimes the floor, must be constructed in such a way that water vapour cannot penetrate to the insulation. However, if some water vapour does manage to penetrate to the inner portion of the wall, it must not be allowed to accumulate within the wall. The outer portion must be sufficiently permeable to allow the vapour to escape to the exterior.



Thus, there are two important requirements. First, that provision of a vapour-resistant material must be made on the *warm* side of the structure, and second, that all materials of the structure between the vapour-resistant material and outdoors must allow easy passage of any water vapour through the materials to the outside air. This includes the material known as sheathing paper, which is used to protect the outer portions of the structure from wind-driven rain and snow.

INSIDE PROTECTION: *Vapour Barriers*

Let us consider the first requirement of keeping the moisture from passing through the interior finish of the wall or ceiling to the inner structure. Any material that will permit only very small amounts of water vapour to pass through it is called a vapour barrier. There are three types of vapour barriers which can be used in a house. They are:

1. *Suitable building papers and foils;*
2. *Asphalt film on or in fibreboards;*
3. *Paint films.*

The following is a list of some of the building papers and foils that can be classed as vapour barriers:

Asphalt saturated and coated sheathing felts;
Asphalt saturated and coated kraft papers;
Asphalt coated kraft papers;
Duplex papers;
Heavy roofing papers;
Infused papers;
Aluminum foils;
Copper foils.

Among the paints that will act as vapour barriers are aluminum paint, asphalt and varnish vehicle paint. How-

ever, these do not provide a vapour barrier that is as reliable as a paper type barrier. It is recommended, therefore, that a paint vapour barrier be used only where a paper or foil cannot be incorporated in the wall.

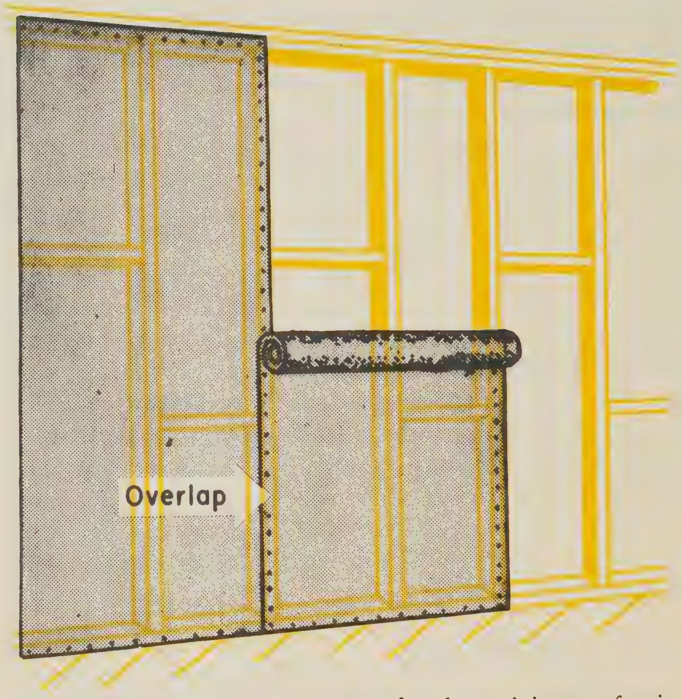
There are no definite rules as to which type of vapour barrier should be used; this is generally left up to the architect or builder. As a general rule, where wall board or furring strips and lath and plaster are used, the sheet type of vapour barrier will be an effective method of resistance to water vapour. For floors over crawl spaces, the sheet type of vapour barrier is usual practice. Insulating plaster base or asphalt-coated board may be used under plaster, provided the joints are made in such a way as to give a continuous, unbroken barrier. If aluminum paint is used on new plaster, a sealer coat of paint is necessary, prior to the aluminum paint. This protects it from the free lime in the plaster. After this sealer coat, two coats of aluminum paint are applied, followed by one or two coats of a finishing paint, depending upon the coverage required.

Where TO INSTALL

All walls, ceilings, and floors over cold crawl spaces, which require heat insulation, will also require vapour barriers installed on the *warm* side of the insulation.

Installation OF VAPOUR BARRIERS

If sheet type vapour barriers are not installed properly, they will not offer the service they should. It must be emphasized that great care must be taken when installing this type to be sure that there are no cracks or loose joinings. An overlap of sheets is necessary for an effective barrier.



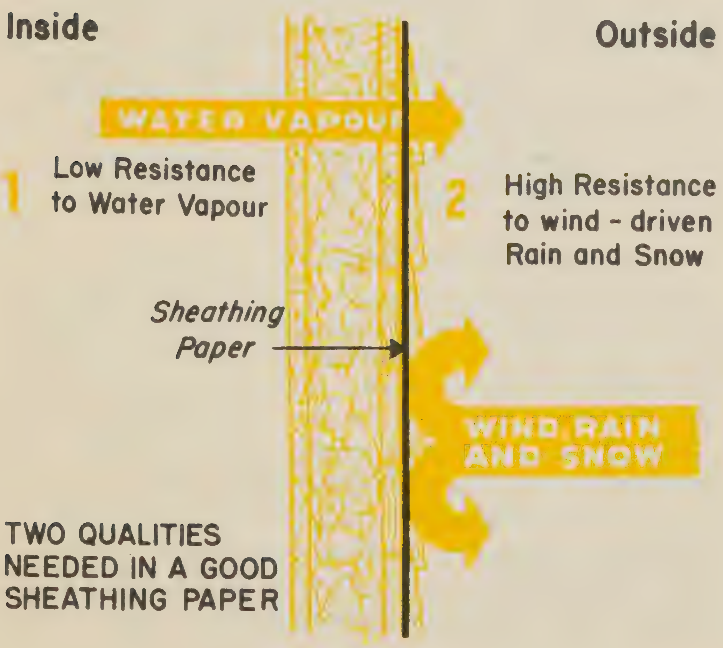
All joints should occur at studs, plates, joists, or furring strips. The edges of the sheets must be fastened securely and as continuously as possible so as to leave no gaps between the sheets and the framework.

OUTSIDE PROTECTION: *Sheathing Papers*

Let us now examine the second requirement in the prevention of condensation. As it is not economically feasible to install a vapour barrier so that it has absolutely perfect resistance to water vapour, means must be provided whereby

the vapour that *does* pass through the barrier can escape readily to the outside air. This may be accomplished by choosing materials that are not resistant to the passage of water vapour.

Sheathing or building papers which protect the outside of the wall from wind-driven rain must allow the vapour to escape. Thus it can be seen that vapour barriers and sheathing papers each have a very different service to offer the occupants of a house. They cannot be interchanged and the prospective home owner or builder is urged to make sure that



TWO QUALITIES NEEDED IN A GOOD SHEATHING PAPER

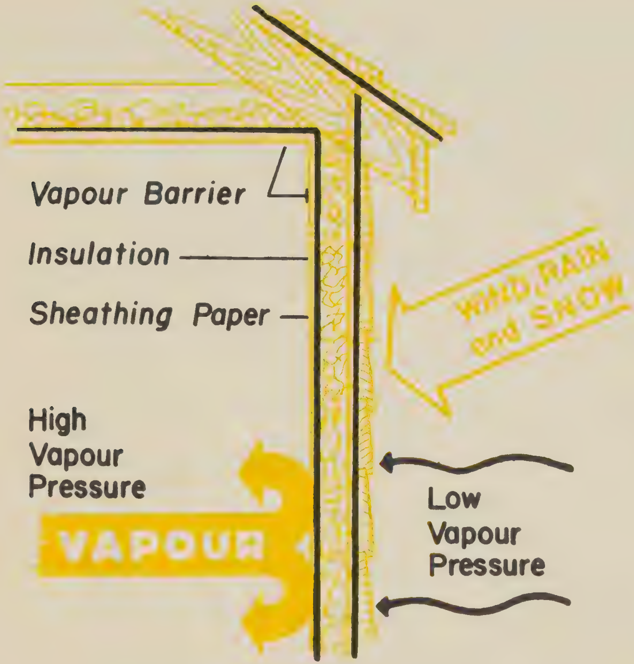
the correct material for each service is used. If a material which is a vapour barrier is mistakenly placed on the outside of a house, even more extreme conditions for condensation will be set up inside the wall structure.

Ventilation OF ATTICS AND ROOFS

Ventilation has proved of great value in reducing moisture problems in attic spaces and on the under side of flat roofs. Condensation occurs in attic spaces and flat roofs in the same way as it does in walls. It collects as frost or ice on the roof boards, on projecting nails and frequently between the roof sheathing and exterior covering. When the temperature rises, this frost will melt, causing possible decay of the roof members and much damage by the moisture dripping down on to the insulated ceiling or down the outside walls. In addition, the insulation may become very wet and as it retains moisture for a long time, rotting of studs may be a result. Another result may be the damaging of interior wall finishes.

It is general practice nowadays to install louvered openings in the gable ends of houses to provide ventilation through attic spaces. When these function properly, there is usually little or no condensation. Often, however, they are too small or do not face prevailing winds and for other reasons do not give the service they should. Again, the householder often mistakenly does not leave these vents open in an attempt to conserve heat and the intended protection is lost.

The problem of condensation in attic spaces is aggravated because most roofing materials, being asphaltic, tend to prevent the passage of water vapour from the attic through the roof. In order to be as sure as possible that you will not



be bothered by condensation problems in attic spaces, a combination of vapour barriers and proper ventilation is recommended.

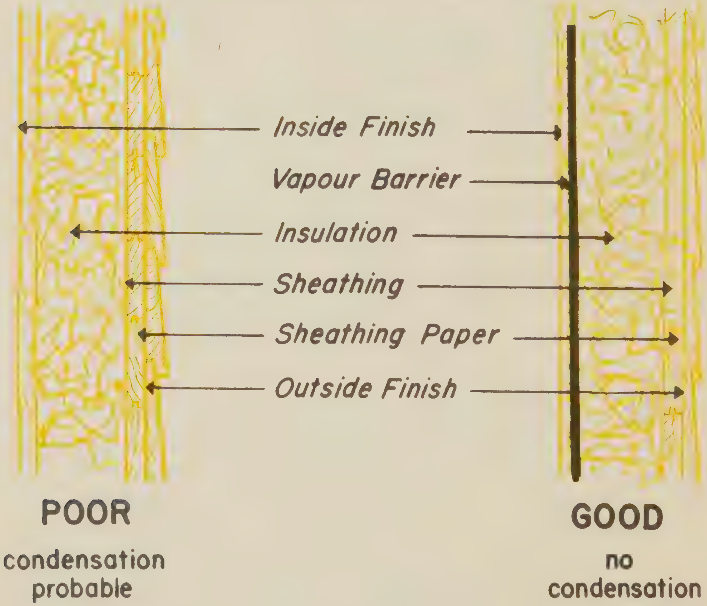
Summary

Every home owner and prospective home builder should make sure that proper vapour barriers are installed in his house; this measure will pay dividends in later years.

This booklet is not intended as a technical report on the problem of protecting a house from condensation within the structure. Rather it is written to bring to the notice of

builders and home owners certain aspects of condensation which can cause extensive damage to a building. This damage can be avoided and much expense saved if, in the construction of a dwelling, suitable materials are installed which will function as vapour barriers and sheathing papers.

COMPARISON OF TWO WALLS



If a more detailed, technical account is desired, the following papers are suggested. Copies of these may be con-

sulted in most technical libraries or may be obtained by writing directly to the offices or organizations indicated.

BABBITT, J. D. *Diffusion of water vapour through various building materials.* (Canadian Journal of Research, v. 17, p. 15-32, Feb. 1939). Published by N.R.C., Ottawa.

BABBITT, J. D. *The permeability of building papers to water vapour.* (Canadian Journal of Research, v. 18, p. 90, May 1940). Published by N.R.C., Ottawa.

CLOSE, P. D. *Thermal insulation of buildings.* Reinhold Publishing Company, New York, 1947, 104 pp.

HUTCHEON, N.B. *Protection of insulation in buildings against condensation.* (University of Saskatchewan, College of Engineering, 210/41).

ILLINOIS, UNIVERSITY OF. *Small Homes Council bulletin F6. 2. Moisture condensation.* (v. 44, No. 34, Jan. 1947).

ROWLEY, F. B., ALGREN, A. B. AND LUND, C. E. *Condensation of moisture and its relation to building construction and operation.* (In Heating, Piping and Air Conditioning, Keeney Publishing Company, 6 N. Michigan Ave., Chicago 2, Illinois, v. 11, pp. 41-49, 1939).

TEESDALE, L.B. *Condensation problems in modern building.* U.S. Forest Products Laboratories, R1196, Madison, Wisconsin, 1939, 10 pp.

WOOLLEY, H. A. *Moisture condensation in building walls.* U.S. National Bureau of Standards, Report BMS63, Washington, 1940, 14 pp.

YORK, J. L. *Vapour barriers with annotated bibliography.* U.S. Office of Production Research and Development, Project M544, Washington, Feb. 1945, 35 pp.

The National Research Council

The National Research Council owes its existence and phenomenal growth to the two world wars. It was founded in 1916 and won its spurs in the second conflict. At the beginning of World War I there were more trained scientists in a few of the great German industries than could be found in the entire British Empire, and German scientific resources were much better organized. To cope with the situation, the British Parliament set up a committee in 1915 to foster a scheme of scientific and industrial research for the United Kingdom. Excellent results were achieved and early the following year the Secretary of State for the Colonies recommended the idea to the various Dominion Governments.

Canadians were already aware of the need for organizing industrial and scientific research in Canada and acted promptly. On June 1, 1916, a committee of six cabinet ministers was formed to foster the scientific development of Canadian industries, both for war and post-war needs. In November, this committee appointed an Honorary Advisory Council for Scientific and Industrial Research. This body, better known by the short title National Research Council, was composed of eleven representatives (later increased to fifteen and recently enlarged to twenty) of the scientific, technical and industrial interests of Canada. Among the duties assigned to this body was that of linking science with labour and capital to bring about the best economic results. It was also important to find means of stimulating research work in Canada, of increasing the number of trained research men and of co-ordinating their work.

Problems were brought to the attention of the Advisory Council by scientific workers throughout the country, and, if an applicant was qualified to direct a research project and had adequate laboratory facilities at his disposal, a grant was made to provide him with necessary help or with additional specialized equipment. This system of assisted researches met with extraordinary success and still plays a vital role in the Council's program. Similarly, if a scientific problem is of national importance, or of broad scope involving several fields of science, the Council may take the initiative in inviting scientists, industrialists and others concerned to become members of an associate committee on the problem. Such committees are responsible for advising the Council which poli-

cies should be followed and where the work can best be done; they are also provided with funds to support the investigations they sponsor.

One of the important problems facing Canada in 1916 was to increase the number of trained scientists in the country. The Council established a system of scholarships for students who had demonstrated their ability for original research. Students at all the principal universities of Canada have benefitted by these awards. This policy has paid excellent dividends. During World War I, Canada had few available scientific workers but in World War II, a large body of highly qualified research workers enabled her to play an important part in the scientific activities of that conflict.

In 1916, Canada had no National Research Laboratories, no Bureau of Standards, no National Physical Laboratories and no privately endowed institutes for research. The Council early recommended the establishment of national laboratories. Although the Government supported the plan from the first, there was little public appreciation of the need for scientific research in Canada and it was only after more than a decade of continuous public education by the Council that in 1927 the first temporary laboratories were set up in the Bryson Building on Queen Street. In 1929 these were moved to buildings on John Street, at the junction of the Rideau and Ottawa Rivers. In 1928 funds were provided for a new building, which was begun in 1930 on the Sussex Street site and was opened at the time of the Ottawa Imperial Conference in 1932. Four divisions were organized: Physics and Engineering, Biology and Agriculture, Chemistry, and Research Information.

In 1936 the Division of Mechanical Engineering was established as a separate division in the John Street buildings. These quarters soon became inadequate and early in 1939 a site of 130 acres was obtained on the Montreal Road adjacent to the Rockcliffe Air Station. The advent of war hastened the construction of new engineering buildings on this site. These laboratories had a direct wartime use and include buildings for research on aerodynamics, engines, fuels and lubricants, hydraulics, explosives, and structures.

By 1940 the National Research Laboratories were engaged in almost every field of war research and peace time operations had been reduced to a minimum. The closest co-operation was maintained with Government departments, industry and universities. The Laboratories were designated as the research establishment of the Navy, Army and Air Force. Facilities in many

fields were inadequate and it was necessary to expand them rapidly. Staff and expenditures increased more than sevenfold with corresponding expansion in the diversity and extent of activities sponsored outside the Laboratories. In the later years of the war the National Research Council was responsible for research in more than a score of establishments scattered across Canada from coast to coast and workers were engaged in research in all the various war zones outside Canada.

After the end of hostilities, a number of laboratories exclusively concerned with war investigations were closed and others were modified to suit post-war needs. Radio research, which grew from a single laboratory in 1939 to a large branch, became associated in 1946 with Electrical Engineering laboratories in the main building and was established as a division in 1947. The largest wartime undertaking to survive in the post-war period is the Atomic Energy Project. It was initiated in November, 1942, as a secret laboratory and for more than two years work was carried on in a wing of the University of Montreal. The transfer to a new site at Chalk River was completed early in the summer of 1946. In the same year, the Mechanical Engineering Division opened a Flight Research Station at Arnprior, and a new building was begun to house the Prairie Regional Laboratory at Saskatoon, set up under the Division of Applied Biology to promote studies on crop utilization.

During the past fifteen years public support for the work of the National Research Council has grown steadily. Although most of its accomplishments do not become known beyond the scientific or industrial groups directly interested, a number of achievements have gained wide recognition. The Government's decision to continue the National Research Council at its wartime strength gives the staff the opportunity to serve Canada still further and to maintain her position in the scientific world.

DIVISION OF BUILDING RESEARCH

The National Research Council has long been concerned with the special problems of the construction industry, having appointed its first committee in this field as early as 1932. Consideration was given in succeeding years to the best way of meeting the special research needs of building but the incidence of the World War prevented actual progress in this field, apart from the investigations into special building problems which were being carried

out by existing divisions of the Council, notably those of Physics, Chemistry, and Mechanical Engineering. Towards the end of the war, building research was again under review; the decision was finally reached that a new Division of Building Research should be set up. This was done, although the actual start of the new Division did not take place until 1947. One reason for this further delay was that the new Division was intended to work closely with Central Mortgage and Housing Corporation which was only then starting its important work as the agency for the Federal Government in the housing field.

Provision of a complete research service to the construction industry of Canada—one of the major industries of the country—is the ultimate objective of the new Division. In keeping with this long-term objective, the Division has already forged useful contacts with many parts of this great industry; it is already a member in full standing of the Canadian Construction Association. In co-operation with the Association and its member firms, the Division looks forward to carrying out much of its work on actual construction jobs—which will constitute, in effect, some of its most important laboratories. Studies of local soil and foundation conditions are envisaged and have already been started in a modest way. Other job problems will include such questions as the pressure on bracing and retaining walls, deterioration of building materials, groundwater studies, the actual strength and deformation of structures, settlement of buildings and the investigation of unusual failures.

Laboratory studies will follow more commonly appreciated lines. New building materials will be studied and the actual performance of familiar materials investigated. Routine testing will not be carried out when such work can be performed by commercial testing laboratories with which the Division hopes to co-operate closely, a directory of all such laboratories having been the first publication of the Division. Correspondingly, it is hoped that broader programs than in the past of laboratory studies of building problems can be carried out by the universities of Canada with financial assistance from the Council, channeled through and co-ordinated by the Division. The Division itself plans to provide research and testing facilities of unusual size and complexity for the study of such special Canadian problems as those of wall construction, thermal insulation and vapour resistance characteristics of building materials, and—of special importance—for the whole field of fire research in relation to building.

In all this work, the Division

expects to co-operate closely not only with the other Divisions of the Council but also with all other bodies in Canada concerned with building research in any of its more specialized aspects, such as the Forest Products Laboratories and the Bureau of Mines of the Department of Mines and Resources, the Testing Laboratories of the Department of Public Works, the Meteorological Service of the Department of Transport and with the Bureau of Statistics. The Division is also working closely with provincial research organizations and with such research laboratories as those of the Ontario "Hydro".

Although ultimately a broad program of research into many aspects of building will be carried out, the special claims of housing are naturally receiving special initial attention in view of the continuing critical state of housing in Canada. In this work, the Division is working very closely with Central Mortgage and Housing Corporation which it serves in an advisory capacity, and as its technical "research wing". Studies are also being made of such problems as the deterioration of paint on wooden houses, the construction of houses on flat concrete slabs, and cavity wall construction—which have arisen through the work of the Corporation. Field studies are planned of house construction; experimental houses will be built, two having already been completed at Ottawa. As its part of this co-operative program, the Corporation is investigating community and site planning, and the planning and layout of housing units.

Building codes exert an important influence on all house building; the National Building Code has, therefore, been made a responsibility of the Division. This notable document was published in 1941 as a result of a great deal of work by many technical committees. A new Associate Committee on the National Building Code has, therefore, been set up by the Council and its work will now be serviced by staff of the Division. It is planned to keep the Code continually under revision and to publish such other documents as will assist in developing uniformity and high technical standards in local building codes across the Dominion. Publication of useful literature will always be an unusually important part of the work of the Division. Publications will include not only technical and research papers but also bulletins on better building practice for general use.

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NUMBER

INSULATION OF THE HOME

2

Division of Building Research
National Research Council

TEN CENTS

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This is one of a series of
bulletins on Better Building Practice;

it deals with

INSULATION
OF THE HOME

and was prepared by

W. H. Ball
Division of Building Research

February 1956
Revised February 1967

Les autres bulletins de cette série seront disponibles en français aussitôt que possible. Deux, intitulés *La Condensation dans la Maison* et *Les Travaux d'Hiver* ont déjà été publiés. Pour être tenu au courant de la publication des versions françaises de ces bulletins, s'adresser au Conseil National de Recherches, Division des Recherches en Bâtiment, Ottawa 7, Canada.

Insulation of the Home (BBB 2) has been prepared as a companion booklet to *Condensation in the Home* (BBB 1).

Much of the information contained in this booklet is based on reports published in both Canada and the United States. In some cases direct reference has been made to work done by others, but general acknowledgement is made here of the help provided by the large volume of previously published information.

An attempt has been made to present sufficient information for a general understanding of the nature and function of insulation, and the importance of good installation practice has been emphasized. Because of the limited scope and size of the booklet the information given may not apply to special cases or circumstances. Where unusual conditions exist guidance should be sought from individuals or agencies with technical training and experience in the field.

A list of selected references is included at the end of this booklet.

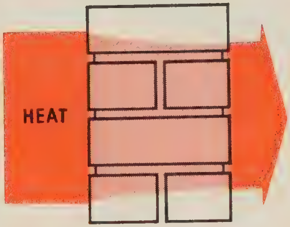
CONTENTS

WHAT INSULATION IS

Any material that has a relatively high resistance to the flow of heat may be used as thermal insulation.

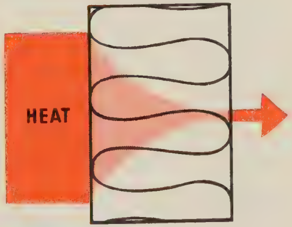
Structural materials in the thicknesses and arrangements commonly used in buildings provide little resistance to heat flow. It has, therefore, become good practice to use insulation to reduce heat loss.

Brick, tile and most types of concrete provide little resistance to heat flow in the thicknesses or forms commonly used. Lightweight foamed masonry materials have much greater resistance to heat flow.



Wood has much greater resistance to heat flow than most masonry materials, but when used for framing, sheathing and cladding, as in wood-frame construction, it does not provide adequate resistance to heat loss.

Insulation has relatively high resistance to heat flow when compared with other materials.

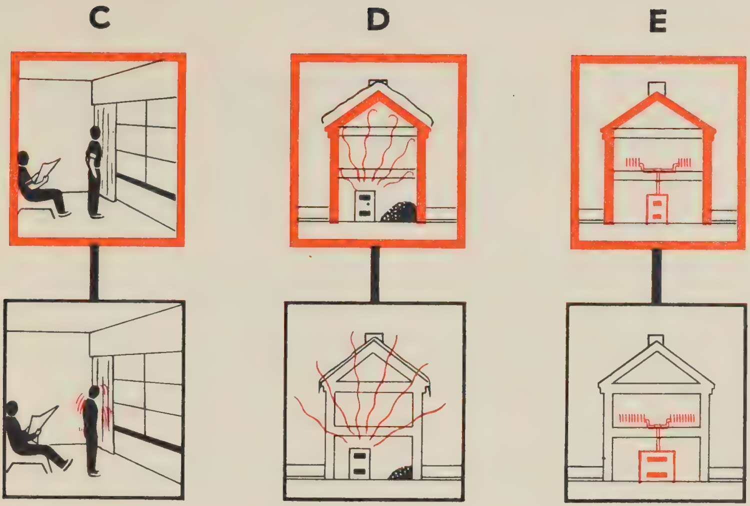


WHAT INSULATION CAN DO

Substantial thicknesses of thermal insulation placed in the walls and ceilings of a house will assist in providing conditions of comfort and heating economy.

COMFORT will be possible because the inner surfaces of the exterior walls and ceilings will be more easily warmed and thus will not attract excessive heat from the body or produce drafts. Too speedy a loss of body heat, especially in winter, will cause a sensation of discomfort. The use of insulation in the walls and ceilings of rooms having large uncovered windows may have little effect on comfort.

Drafts may be caused when the air adjacent to walls and windows loses its heat. On cooling, the air becomes more dense and moves downward. At floor level it moves horizontally as a draft. Insulated walls and ceilings with inside



surface temperatures near room air temperatures will produce few drafts.

Temperatures throughout a well-insulated house will be more uniform. This assists in providing comfort, since small variations in temperature are not generally felt by the body.

ECONOMY of heating can be achieved because considerably less fuel will be required to heat the house. In new houses or where a heating system is to be replaced, smaller, less costly heating equipment will be necessary.

The heat losses from about 200 homes were studied* and it was found that on the average the heat losses from these homes could be divided approximately as shown in the following table. The houses examined were of wood-frame construction with basements, were uninsulated, and had no storm windows, storm doors, or weatherstripping.

*(Factors Affecting Fuel Saving, by S. Konzo, Circular No. 26, Engineering Experiment Station, University of Illinois.)

It may be seen from the following table that the greatest proportion of the total heat loss is through and around windows and doors (combine items 2 and 3).

	Type of Heat Loss	Percentage Total Heat Loss
1.	Through walls and ceilings	43
2.	Through windows and doors	30
3.	Loss of warm air through cracks around windows and doors	25
4.	Through floors to basement	2
		100

The following conclusions were obtained from this study:

(a) The use of storm windows and doors would decrease the total heat loss by 31%.

(b) The use of 2 inches of insulation having a "k" value of 0.27, or its equivalent, would also decrease the total heat loss by 31%.

(c) The use of weatherstripping would decrease the total heat loss by 10%.

Considering items (a) and (b) above, the use of 2 inches of insulation and storm windows and storm doors would, taken together, reduce the total heat loss by 62%.

The question of insulation thickness is discussed on page 12. The use of storm windows and doors will greatly reduce the loss of warm air around windows and doors. Weatherstripping or sealing of storm windows and doors should not be attempted, in order to allow air that may get by the inner window or door, and the water vapour it carries, to move freely to the outside.

Weatherstripping should be used only on inner windows and doors that are poorly fitted, or when double glazing is used in a single sash.

TYPES OF INSULATION

Fill Insulation includes such materials as mineral wool (which is a general term applying to rock wool, slag wool, and glass wool), wood shavings, shredded redwood bark, and expanded vermiculite.

Batt and Blanket Insulation may be formed from a variety of materials including mineral wool (commonly glass or slag wool), cotton fibres, eel grass, and processed wood pulp. The material is either loosely felted or combined in multiple layers and is attached to a backing paper with asphalt or other adhesive, or in some cases is loosely stitched to the backing. It is then cut into 2-foot, 4-foot, or 8-foot lengths, or is left in much longer lengths for cutting on the job. Some products have a light paper attached to the backing that, with the backing, forms an envelope completely enclosing the insulating material.

Products of this type are generally manufactured for use between studs and joists spaced at 16- or 24-inch centres.

The backing paper on batt and blanket insulation is usually manufactured to have a high resistance to water vapour flow, and it may qualify as a "vapour barrier". See page 26 for further information.

Reflective Insulation may be available in two forms:

(1) as shiny metal foil carried on one or both sides of a heavy paper or cardboard and intended for installation between framing members by stapling or fastening with nailed wood-strips. This type of product should be carefully *sealed* to the framing members on all sides to form separate, unconnected air spaces at least ¾ inch thick. If air can pass freely from one space to another, much of the benefit of the reflective curtain may be lost.

(2) as a blanket-type product which, after cutting to an appropriate length, can be expanded accordian-like to provide two or more air spaces faced on one or both sides with shiny foils. It may be fastened to the interior face of the framing members or between them, depending on the design of the product.

A reflective surface must face an air space to be effective as insulation. For a given arrangement the effectiveness of reflective insulation depends on the direction of heat flow (upward, downard or horizontal). Compare ratings on pages 28 and 29. Note that it performs best when the direction of heat flow is downward.

Insulating Boards (Fibreboards) consist of relatively stiff boards manufactured from fibres obtained from wood, corn stalks, waste paper, sugar cane and straw. They are used as sheathing, as a plaster base, and as an interior finish. In the thicknesses commonly used for such purposes they do not always provide sufficient insulation when used as the principal insulating material.

Foamed Plastic Insulation

(1) Polystyrene insulation is produced in board or panel form either by a single-stage foaming or expansion process, or by the two-stage expansion process. In the latter case beads of polystyrene are formed first, and are subsequently expanded a second time in a mould. Boards of various thicknesses are then sawn—they are commonly called "beadboard".

(2) Polyurethane insulation is produced by a foaming process in the form of boards or panels which may be flexible or relatively rigid. Polyurethane resins may also be sprayed or foamed-in-place for special installations.

TECHNICAL RATING OF INSULATION

The effectiveness of an insulation is commonly expressed in terms of its ability to conduct heat, and is represented by its "k" value. The lower the "k" value the better the insulating value of the material. This value is the number of British thermal units of heat that will pass through a sample of the material 1 square foot in area and 1 inch thick in 1 hour, when there is a temperature difference of 1 degree Fahrenheit between one face of the sample and the opposite face.

Standard laboratory tests have been developed for determining the "k" values of insulating materials and most suppliers of building materials can provide these figures. Such values should preferably be based upon tests conducted by independent testing laboratories. Laboratory tests are made on dry samples of material.

"k" values are useful for making comparisons of various materials and are used in estimation of heat losses and gains for buildings for the design of heating and cooling systems. They do not, however, necessarily represent the actual performance of a material in a wall or ceiling. "k" values are known, for example, to be affected by the density of the material and by its moisture content.

Reflective insulations in combination with air spaces, and other materials used in specific thicknesses, are rated in terms of thermal conductance, "C". The "C" value is stated in the same terms as "k" except that no thickness is included.

On page 5 the term "resistance to heat flow" is used. This term is represented by the letter "R" and is the inverse of thermal conductivity and thermal conductance. Thus

$$R = \frac{1}{k} \text{ or } R = \frac{1}{C}$$

The number obtained is a direct indication of insulating value—the higher the "R" the better the insulating value.

HOW MUCH INSULATION TO USE

Several factors affect the amount of insulation that should be installed in a house. Most important are the cost of fuel, the severity of the climate, and the cost of insulating which must include the cost of the insulation plus the cost of installation.

If fuel in a particular area is very cheap, then it may not be economical to provide more insulation than that provided by the structural enclosure itself. If the cost of fuel is high, however, in relation to the cost of insulating, then it becomes advantageous to use a substantial thickness of insulation. This latter situation generally applies, so that insulation can be recommended to minimize heating costs, to improve comfort, and to conserve the nation's fuel resources.

A detailed study of insulation requirements has been published as Housing Note 21, *Insulation Thickness for Houses* (reprinted from *Canadian Builder,* Vol. XIV, No. 11, November 1964), and can be obtained from the Division of Building Research, National Research Council, Ottawa, without charge.

On the basis of this study it may be said that for most of Canada it is economical to fill the stud spaces in wood-frame walls with insulation and to use an equal or greater thickness in ceilings.

Where electric heating is used, about twice the thickness of insulation can be justified, but normally this additional insulation would be added only to ceilings.

FACTORS TO CONSIDER IN SELECTING AN INSULATION

The two most important considerations in the selection of an insulating material are its "k" value and its cost.

"k" Value

Materials having "k" values of about 0.30 or less are generally considered as insulation. Some dual-purpose materials, i.e. those that also make a contribution to structural enclosures have "k" values greater than 0.30 and can be justified as insulation because of the greater thickness used.

Cost

A comparison of the cost of insulations should include consideration of the cost of their installation. Two insulations of the same cost would not compare favourably if one was considerably more expensive to install.

Other Desirable Properties in an Insulation

It should not present a fire hazard—Combustible insulation and paper-enclosed batts and blankets will increase the fire hazard when used in attics.

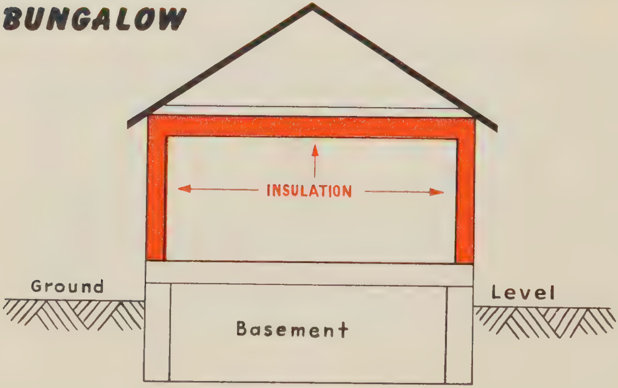
Where wall spaces are completely filled with insulation that will not burn, the rate of fire-spread will be reduced substantially; and even the use of combustible insulation in this way will probably not present an increased hazard. If a fire does occur in a wall or attic insulated with combustible insulation, it will be difficult to extinguish.

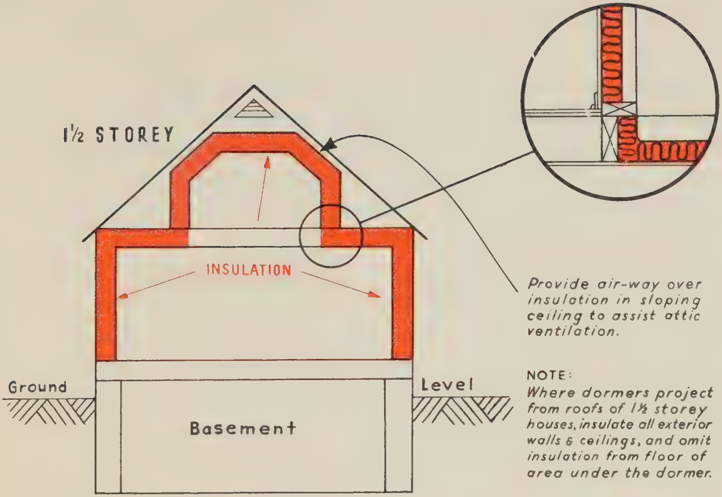
It should not settle—Vibration and wetting with water are the principal factors that cause settlement. In this respect well-formed and supported batt and blanket insulations and board or panel type insulations have the advantage because they are unlikely to be affected by such conditions.

It should not attract insects, rats or mice—No evidence is available to show that any of the common insulating materials attract insects, rats or mice, but some materials (soft and non-irritating) may provide suitable living conditions for them. Various treatments have been proposed to make low-cost materials such as wood shavings insect resistant, but it is doubtful whether such treatments are effective, durable, or economical.

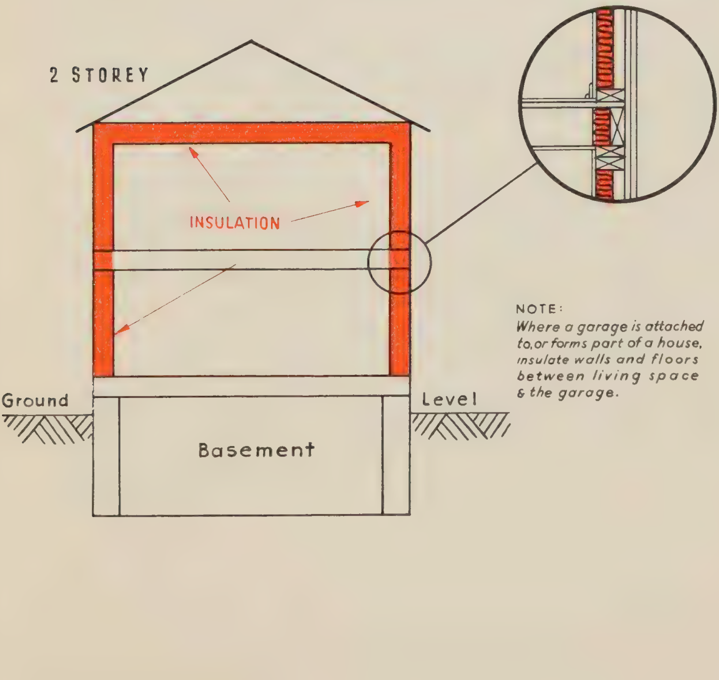
WHERE TO INSULATE

BUNGALOW





NOTE:
Where dormers project from roofs of 1½ storey houses, insulate all exterior walls & ceilings, and omit insulation from floor of area under the dormer.



NOTE:
Where a garage is attached to, or forms part of a house, insulate walls and floors between living space & the garage.

INSTALLATION OF INSULATION

Much study and test work has been involved in the development of modern insulation materials, and in the determination of insulating qualities and other physical properties. This type of information has been described and is useful in selecting a material for a particular insulation job.

Field experience has demonstrated that in spite of the fact that careful consideration may have been given to the selection of insulating materials, they have not always performed in the manner anticipated. More troublesome conditions have, in fact, been produced in some cases than those that would have existed if no insulation had been used. Numerous field investigations and laboratory tests indicate that such conditions are due to faulty installation and the form or shape in which an insulation material is used. The following notes and sketches have been prepared as a guide for the installation of insulating materials. They will also be useful in assessing the probable performance of a product.

The importance of careful installation of insulation is of more concern in areas subject to low temperature, and therefore the following suggestions apply particularly to such areas. The results of improper installation may not be as severe in areas having a mild climate.

Most manufacturers of insulating material supply installation instructions. These should be carefully followed. The details that follow are intended to supplement such instructions and to emphasize details considered important.

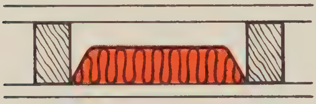
SPACES TO BE INSULATED

Spaces in walls, floors, and ceilings in which insulation is placed are generally rectangular in shape. Ideally, it would be of advantage if these spaces were of uniform width, so that it would be relatively simple to use a manufactured insulation of standard width. In practice, spaces to be insulated are seldom of standard width.

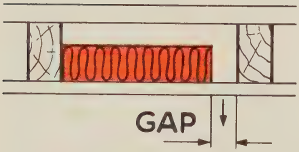
A survey of 77 houses under construction in nine Canadian cities indicated that, on the average, approximately one-third of the wall area of the houses measured, excluding window and door openings, had stud spacing unsuited to standard widths of insulation. This situation indicates that more care should be given to the framing of houses, and reveals that it is necessary to modify standard-width insulation on the job if good installation is to be achieved.

Fill insulations and board-type insulations applied to the interior or exterior faces of studs are not greatly affected by this situation; the ease of installation and effectiveness of batt and blanket types of insulation may be seriously affected. Thus the ease with which a particular product may be fitted to a space may be an important factor in its selection. Insulations difficult to cut to a desired width or those that cannot be installed in the intended manner will be at a disadvantage. For example, some very light woolly materials may be difficult to cut without damaging the product; blanket insulations that depend on running stitching to maintain their form may be rendered useless by cutting; and some forms of reflective insulating blankets are unsuitable for use in spaces of non-standard width.

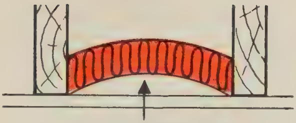
Insulation Should Fit Snugly Against Framing Members



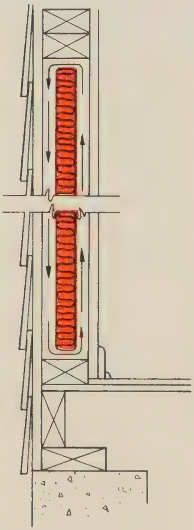
This illustrates an inferior form of insulation. The insulating material does not fit against the framing members, so that they are exposed over their whole width to the cold air in the outer wall space. The interior wall surface over the framing member will be colder than necessary, and dust marking and surface condensation may occur. The heads of nails driven into framing members so exposed will create local cold spots on walls.



In this illustration the space between framing members is too wide. A gap results which, if not filled, will allow heat to by-pass the insulation. The interior wall or ceiling surface over the gap will be at a lower temperature than the wall surface temperature over the insulated area. Unnecessary heat loss will result. Dust marking and surface condensation may occur. To prevent this, cut the batt or blanket into lengths which, when placed crosswise, fill the width of the space completely. In ceilings the insulation may be installed as indicated and the resulting gap filled with additional insulation.

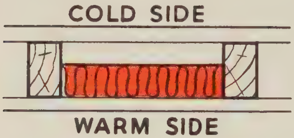


In this illustration the space between framing members is too narrow for a standard width insulation. If the insulation is deformed in installation, as illustrated, an air space is formed on the warm side of the insulation. This is particularly objectionable in a ceiling where the air space is open to the attic at each end or between lengths of insulation. A by-pass for heat loss may result and cold air may enter the space from the attic. Dust marking on the ceiling surface between joists may occur. The insulation should be cut to fit the space.

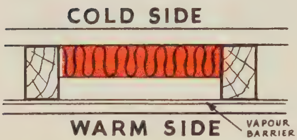


If the insulation is installed midway in a wall space, as illustrated, with only a slight gap top and bottom, heat will by-pass the insulation (see arrows), due to the natural circulation of air in the wall spaces. If this occurs much of the value of the insulation will be lost.

Location of Insulation in Spaces



Recommended where vapour barrier on insulation is only vapour protection.



Insulation located in this manner will provide least interior surface temperature variation.

Note: Additional vapour barrier to that on batt or blanket is essential.

When insulation that does not fill spaces is to be used its location should be carefully considered. The location of insulation may affect the surface temperature pattern on walls. Generally speaking, surface temperatures will be more uniform when the insulation is installed at the cold side of the spaces. Where the backing of the insulation is to act as the only vapour barrier the insulation should be installed on the warm side of the spaces. No general recommendation as to the best location for insulation can be made in view of the variety of circumstances may affect wall performance.

The thickness and type of the interior finish and the "k" value of the insulation may also affect interior surface temperatures.

Placing of Fill Insulation

The placing of fill insulation on ceilings in houses with attics is a relatively simple operation. It may be blown into the spaces between the joists or removed from the bag, loosened, and worked into place by hand.

The placing of fill insulation in walls is more difficult and requires considerable care. In existing houses it is necessary to make an opening into each stud space, and each should be sounded with a weighted string or wire so that obstructions to the easy passage of insulation may be detected.

Firestops, or girts, often placed at the mid-height of walls, and bracing set in between the studs should be located so that additional openings may be located below them. Generally, it is possible to make a satisfactory job of insulating existing walls only by blowing the insulation into the wall spaces. The effectiveness of blown insulation will in turn depend on the skill and experience of the applicator.

Most fill insulations do not lend themselves to easy application in new construction.

INSULATION OF MASONRY WALLS

Standard practice in the insulation of masonry walls has required that spaces be created on the inside of walls by the use of wood furring strips so that insulation can be placed between them. It is comon practice to use 2- by 2-in. wood furring (actual thickness 1⅝ in.). In cold climates this often creates dust marking on interior surfaces because of the difference in insulating value of the wood members and the insulated areas of walls. The use of panel type insulation such as corkboard, polystyrene or polyurethane provides a means of applying a uniform layer of insulation over a masonry wall, interior finishes being applied directly to the insulation.

A new approach to the design of masonry walls is described in Canadian Building Digest No. 50 (see Ref. 7).

INSULATION OF BASEMENTS

The heat loss from the average unheated basement is usually not large compared with the total heat loss from the house. The portion of basement walls above grade will, however, have a high rate of heat loss if the basement space is heated. Insulation of basements may therefore be worth while in some cases. If living space is provided in the basement, insulation will improve the comfort conditions over those of an uninsulated basement room and may assist in controlling dampness, especially in regions subject to high humidities in summer.

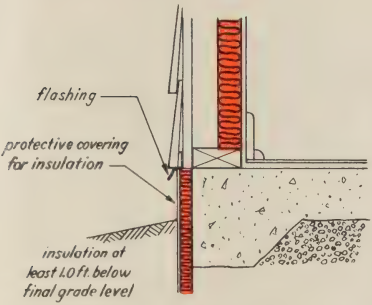
The insulation of basement walls is complicated by the fact that the basement wall is in contact with the soil, generally for most of its height. Thus moisture may enter the wall from the soil and the insulation may become damp. The possibility that moisture may pass into the wall from the interior of the building and condense on cold concrete walls further complicates the problem of protecting the insulation to keep it dry.

In summary, it is apparent that insulation applied against the interior of a basement wall may be subject to wetting as a result of moisture movement in two opposite directions. It will also be apparent that any attempt to seal the insulation against the penetration of moisture from one direction will make more difficult the removal of moisture entering by the other direction.

Suggested procedures for the design and construction of habitable space in basements are given in Canadian Building Digest No. 13 (see Ref. 5).

INSULATION OF FLOORS IN BASEMENTLESS HOUSES

Floors of basementless houses present special problems when considered from the point of view of heat loss and insulation. Unlike houses with unheated basements, heat losses through the floors of basementless houses may be appreciable. These should be controlled by insulation to keep heating costs to a minimum, to assist in maintaining comfort conditions, and to prevent condensation on the floor surface.



The concrete floor illustrated is commonly referred to as a "floating slab" and features an enlarged perimeter section known as a "grade beam". The heat loss from a grade beam will be high unless insulation is provided at the edge of the slab to reduce heat loss.

Where a conventional foundation wall is used in conjunction with a concrete slab floor the insulation may be placed outside the foundation wall in the same manner as that illustrated for the floating slab. Alternatively, it may be placed inside the foundation wall vertically at the edge of the slab, either against the inside of the foundation wall or horizontally under the slab for a distance of 2 to 3 feet.

Basementless houses with wood-joist floor systems also require insulation to control heat loss and to assist in providing warm floors. Two methods of installation are shown.

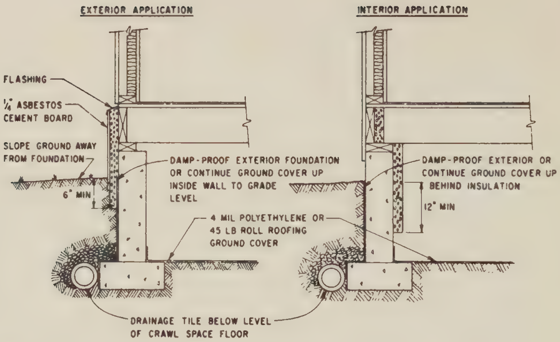
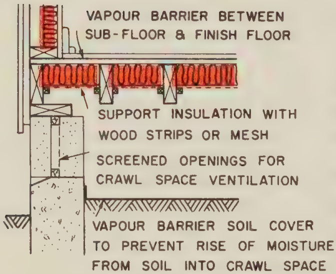


FIGURE 2 — Crawl spaces insulated with rigid foam.



A third method of installation where the insulation is supported between the floor joists directly against the sub-floor is also shown. This is the least preferable of the methods shown and should only be considered where it is necessary to limit heat loss from the house to the ground.

For most cases it is best to use one of the systems where the insulation is installed on the exterior of supporting slabs or foundation walls. In this location it not only controls heat loss but also provides protection against the possibility of ground freezing (and heaving) under foundations.

Insulation placed on, in, or near the ground will probably be exposed at times to extreme moisture conditions. Thus an insulating material for this type of service should have low water absorption, high resistance to water vapour flow

and be rot proof. Foamed plastic, foamed rubber and foamed glass insulation products are available for such applications. These insulations usually have low strength and need protection if exposed to the outside.

It is suggested that sufficient thickness of insulation be used to provide a conductance (C) of 0.20. Thus 1 inch of insulation, having a "k" value of 0.20, or 2 inches of insulation, having a "k" value of 0.40, would meet this requirement.

CONDENSATION IN THE HOME

Although it has distinct advantages, the use of insulation has produced serious problems associated with the movement of water vapour from the warm interior of a house through the inner parts of walls, ceilings and floors to their colder outer parts. These problems are *not caused* by the insulation, but they can occur more readily in insulated houses as a result of the condensation of water vapour into liquid water or ice (frost).

Some of the problems that can occur are: insulation becomes wet and so loses its insulating value; interior finishes such as plaster and wall-board are wetted and damaged; paint (both interior and exterior) may fail; rot of wood members and fungus growth may occur; unpleasant odours may occur.

Water vapour in the air in a house may be moved into walls, roofs and floors in two ways. The leakage of air through cracks can carry moisture which may condense out of the air as it reaches a surface which is below the dew-point. Also, water vapour alone may move through materials under the influence of water-vapour pressure difference. These are natural forces which act in varying

degrees and they include wind, stack or chimney action, pressures built up in ventilation systems, and differences in water vapour content of warm air and cold air.

It is possible to limit the amount of condensation that will take place by:

1. Creating an air seal at or near the interior finish of a wall, roof, or floor. Most materials, particularly when painted, will provide an effective air seal. Air will move readily, however, through cracks around window and door frames, trap-doors, electrical outlets and fixtures, and at joints between components.

2. Installing a "vapour barrier" at or near the warm side of a wall, roof, or floor. A vapour barrier is a material that has a high resistance to water vapour flow. In practice vapour barriers consist of membranes (including special building papers) which carry or are unbroken films of asphalt, aluminum or plastic (commonly polyethylene). Certain paint films will perform as vapour barriers.

For more detailed information on the control of condensation see References.

OVER-ALL THERMAL CONDUCTIVITY OF WALLS, CEILINGS AND FLOORS

The over-all thermal conductivity of building components is designated by the letter "U". This "U" value is expressed in British thermal units of heat passing through 1 square foot of area in 1 hour when there is a 1-degree temperature difference between one side of the component and the other.

"U" values can be obtained by testing building components in a laboratory, but they are usually determined by calculation using known values of "k" and "C" for the various materials making up the component. The "U" values of a number of common constructions are included in the following pages to show approximate values, which may be obtained with and without insulation. Various thicknesses of bulk insulation having a "k" value of 0.27 along with a limited number of applications of reflective insulation are included.

The lower the "U" value the better the insulating value. The insulating value or resistance to heat flow of the whole wall is expressed as

$$R = \frac{1}{U}$$

"U" VALUES FOR WALLS

WOOD FRAME WALLS

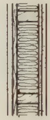
WOOD LAP SIDING, SHEATHING PAPER, WOOD SHEATHING, 2" x 4" STUDS, GYPSUM LATH AND PLASTER.

NO INSULATION

U = 0·22

2 - INCH INSULATION

U = 0·09



3⅝ - INCH INSULATION

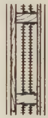
U = 0·06

NOTE:

1. "K" VALUE OF BULK INSULATION = 0·27
2. INDICATES CURTAIN REFLECTIVE BOTH SIDES

CURTAIN

U = 0·12



2 CURTAINS

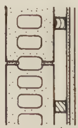
U = 0·09

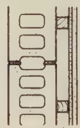
UNIT MASONRY WALLS

8 INCH BRICK, FURRING, GYPSUM LATH AND PLASTER.

8" CONCRETE BLOCK FURRING, GYPSUM LATH & PLASTER.

8" CINDER CONCRETE BLOCK, FURRING, GYPSUM LATH & PLASTER.



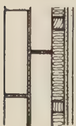


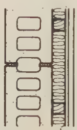
NO INSULATION

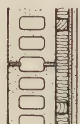
U = 0·29

U = 0·30

U = 0·24







1⅝-INCH INSULATION

U = 0·11

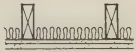
U = 0·12

U = 0·10

"U" VALUES FOR CEILINGS

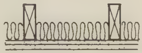
2-BY 6-INCH JOISTS, GYPSUM LATH & PLASTER

U = 0·61



2 - INCH INSULATION

U = 0·11



3 - INCH INSULATION

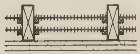
U = 0·08

NOTE:

1. "K" VALUE OF BULK INSULATION = 0·27
2. ╪ INDICATES CURTAIN REFLECTIVE BOTH SIDES
3. "U" VALUES GIVEN ARE FOR UPWARD HEAT FLOW

1 FOIL CURTAIN

U = 0·20



2 FOIL CURTAINS

U = 0·14

"U" VALUES FOR FLOORS

HARDWOOD FINISH FLOORING BUILDING PAPER SOFTWOOD SUB-FLOOR, 2-INCH BY 8-INCH JOISTS

U = 0·28

2 - INCH INSULATION

U = 0·09

3 - INCH INSULATION

U = 0·07

NOTE:

1. "U" VALUES GIVEN ARE FOR DOWNWARD HEAT FLOW

1 FOIL CURTAIN

U = 0·05

2 FOIL CURTAINS

U = 0·04

INSULATION OF EXISTING HOUSES

It will be seen from the foregoing that insulation may best be applied to a house structure at the time the house is built. However, insulation has in many cases been applied in existing houses without there being any visible evidence of damage due to condensation, and with spectacular savings in heating costs. In other cases severe damage has resulted subsequent to the placing of the insulation. Studding and sheathing in the lower part of walls has rotted and has had to be replaced, paint peeling has occurred and ceilings have become damaged due to moisture accumulation in attics. For some cases, at least, this damage might have been avoided had proper precautions been taken.

The problems that result from the use of insulation may be prevented by the creation of an adequate air and vapour barrier on the warm side of the insulation, combined with adequate ventilation of the attic spaces. It is seldom practical to attempt to install a vapour barrier paper in existing walls and ceilings. The only thing that can be done is to apply paint to the interior wall surfaces and provide ample ventilation of attics over insulated ceilings. A considerable measure of vapour protection will result from the application of two or three coats of oil paint, a coat of a varnish-base aluminum paint followed by a decorative finish, or two coats of rubber-base paint.

As there is a possibility that insulation will become wet due to condensation of water vapour within the walls and attics, materials should be selected that do not absorb water easily and dry quickly after wetting without shrinking.

REFERENCES

1. *ASHRAE Guide and Data Book (Chapter entitled Design Heat Transmission Coefficients), published by the American Society of Heating, Refrigerating and Air-Conditioning Engineers. Copies of this Chapter are available as noted below. NRC 7788. Price 50 cents.*
2. *Insulation Thicknesses for Houses, by A. C. Veale. Housing Note No. 21. No charge.*
3. *Crawl Spaces: How to Avoid Trouble with the Foundation, by A. T. Hansen. Housing Note No. 8. No charge.*
4. *Thermal Insulation in Dwellings, by W. H. Ball. Canadian Building Digest No. 16. No charge.*
5. *House Basements, by C. R. Crocker. Canadian Building Digest No. 13. No charge.*
6. *Requirements for Exterior Walls, by N. B. Hutcheon. Canadian Building Digest No. 48. No charge.*
7. *Principles Applied to an Insulated Masonry Wall, by N. B. Hutcheon. Canadian Building Digest No. 50. No charge.*
8. *Points to Watch when Insulating Wood-Framed Flat Roofs, by A. T. Hansen. Housing Note 10. No charge.*

Copies of these publications are available from the Publications Section, Division of Building Research, National Research Council, Ottawa.

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